Development of Injection Material for Offshore Structures Using Flyash-Surfactant Mixtures

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Abstract

In recent years, many waste disposal sites have been conventionally constructed on land in Japan. However, there are limitations to constructing these sites on land. Thus, construction of the disposal sites by reclamation of nearby seashore has been conducted. Although injection material is required to make the established offshore structure, it has high mobility, and does not bleed, etc. Therefore, an injection material which uses a material mixture of the surface-active agent with flyash has been developed. Usage of flyash instead of cement leads to improved mobility, reduced construction cost and so on.

Considering these points, in order to clarify to at which degree the contents of surfactant affects the properties of the injected flyash mixture into the joints of steel sheet pile for offshore structures, different combinations of flyash, surfactant and water were considered by means of multiple experiments.

Keywords

Flyash; Surfactant; Injection Material; Offshore Structure

Introduction

A large amount of waste is produced by coal preparation plants. The properties of the waste vary depending on the mineralogical contents of the mother rock in which the coal is embedded. The waste quality depends on the method of mining and cleaning. The waste mainly consists of clays, quartz, carbonaceous materials, mica, pyrites, and so on (JFA, 1995). About 80% of coal-ash is now utilized and the remainder is disposed of at disposal sites (Matsui et al., 2000). However, the service life of these disposal sites is limited. It is therefore requested that the percentage of utilized flyash should be increased in all applicable fields in Japan. It is evident, due to the issue of finding new disposal sites, that if cement with flyash added can be used as injection material for natural/artificial openings, then the percentage of utilized flyash will be increased (Sasaoka et al., 2000).

Among the types of man-made pozzolans, flyash is probably the most successful component used in mortar injection. When flyash is added to Portland cement concrete, the same kinds of oxides as those of cement are created. As an injection component, flyash acts, in part, as a fine aggregate and, in part, as a binding component (Nonveiller, 1989). However, heavy bleeding and low fluidity are observed if the cement-flyash water ratio is high. It is necessary, then, to consider a new pozzolan, which is composed of a mixture of flyash, cement and surfactant, enhancing its durability.

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In this paper, in order to clarify to at which degree the contents of surfactant affect the properties of the injected flyash mixture into joints of steel sheet pile for offshore structures, different combinations of flyash, surfactant and water were considered by way of a multitude of experiments.

Application of Flyash Cement Mixed with Surfactant in Offshore Structures

Many waste disposal sites have been conventionally constructed on land in Japan. However, construction

on land is limited by space. Thus, construction of disposal sites using land reclaimed from nearby seashore is carried out. In this case, a steel sheet pile is used as a bulkhead seawall as shown in Fig. 1. Construction of steel piles connects each joint of the sheet pile. Fig. 2 shows the conventional type of joints (P-P, P-T and L-T type connector) (Hozumi et al., 2006). In a connection operation, the volume of space at the joints of the seat piles is vast because the portland/flyash cement slurry is not filled completely at the joint due to its bleeding property. Moreover, if the ratio of cement and water is increased, it is very difficult to be injected into the joint due to high viscosity. As a result, contamination of the surrounding ocean space occurs from the disposal site. In addition, as the stiffness of the joints is weak, failure of the joint or the outflow of the contamination from the disposal site is exhibited. In order to mitigate this problem, application of sealing material composed of flyash cement mixed with the surfactant Viscotop, which has excellent fluidity and filling property, was attempted.

FIG. 1 STEEL SHEET PILE

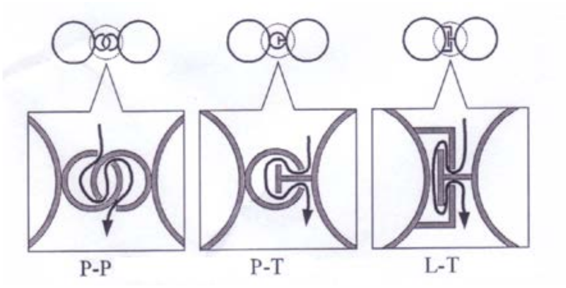


FIG. 2 CONVENTIONAL TYPE JOINT

General Injection into the Joints of the Sheet Pile

The cement slurry is injected into the open joint chamber through a grout tube inserted into the bottom of the joint chamber (Hozumi *et al.*, 2006). The same poly pipe used for flushing can also act as a grout tube. The grout injection continues until the joint chamber is at least 50% full, after which the grout tube shall be progressively withdrawn while grouting continues until the joint chamber is full and the tube has been fully extracted. To fill all voids, pumping of grout will be required. Normally, it is indicated that flowing water followed by grout out of a joint at a stable rate is sufficient evidence that all cavities or voids are filled within the range of the joint grouted; and thus pumping into the joint may cease. Excessive loss of grout is not acceptable. Also, this method will minimize dilution or separation of the grout. The grouting shall be carried out in one single, continuous operation to fill the entirety (6m) of the track. If there is any settlement, the exposed top of the joint chamber must be refilled immediately prior to hardening of the concrete. However, in this case, the volume of space at the joints of the seat piles is great because the cement slurry is not filled completely at the joint due to its bleeding property, as previously mentioned.

Surfactant Viscotop

One of the most effective surfactants with flyash is called Viscotop that is composed of two major components known as Viscotop 100A and Viscotop 100B. The chemical composition of the first part is alkyl arylsulfonate and that of the second part is alkyl ammonium salt. Viscotop 100A is basically a base with a pH between 8-10 and Viscotop 100B is an acid having a pH of between 4-8.

Adding Viscotop to flyash cement can change the properties of the final product. Ordinarily, the same quality of Viscotop 100A and 100B are used as surfactants. The quantity of this surfactant is selected as 0.5-5 percent of the weight of water in the mixture.

Experiments Sample

Among the man-made pozzolans, flyash is probably the most successful component to be used in injection materials. When flyash is added to Portland cement, the same kinds of oxides as those existent in the cement are added. As an injection component, flyash acts, in part, as a fine aggregate and, in part, as a binding component. Fortunately, there is no substantial alteration in the properties of the original component (Davis, 1949, Joshi and Roauer, 1973).

With this in mind, the requisites of sealing materials used for constructing offshore structures are as follows: little bleeding after injection, little separation of the components after injection, sufficient rigidity to withstand tides and waves, and a uniform property

after curing. With these requirements considered, a flow test, two kinds of the compressive strength tests, a permeability test, and other tests were carried out.

The injection material used was that of flyash cement with the surfactant, Viscotop, added, VTFC, mixed with water, cement, flyash, sand, and Viscotop. Table 1 lists the amount of composition of each component of the sealing material. Moreover, the amount of each component of the flyash cement slurry, FC and the antiwashout mortal (AM) are listed as a reference. In addition, the amount combination of Table 1 is indicated as weight (gram) used per one liter of sampled material.

TABLE 1 AMOUNT COMBINATION OF EACH COMPONENT

		Water	Cement	Flyash	Sand
A	VTFC	582	950	150	40
B	FC	445	675	240	600
C	AM	445	675	240	600
		Viscotop	**Admixture**	**Antiwashout agent**	**Dispersing agent**
A	VTFC	A:6.8 B:6.8	60	0	2.0
B	FC	0	4.58	0	0
C	AM	0	13.5	2.5	3.4

Effect of Viscotop on Flyash Cement Mixture Properties

Stability of Injection Material

Fig. 3(a) and (b) show the sporadic dispersion of the flyash cement slurry and the antiwashout mortal in water. Fig. 3(c) shows that VFTC to water could completely bring about stability of the suspension upon pouring into water. It is clear that VTFC does not diffuse in water due to the effect of the surfactant.

Viscosity of Injection Material; Slump Test

Considering the intended application of the mixture with flyash and Viscotop, used on offshore structures, testing of the viscosity or the fluidity characteristics was carried out in the slump test which is defined as the Japanese industrial standard. The dimension of the flow cone device was 51 mm x 50 mm. After the mixture was set into the cone on the glass board, the cone was pulled up from the original position. The mixture spread out after pulling the cone up from the original position, the length of the mixture measured as the flow value. The flow value had good correlation with the yield stress, which is the initial stress of the flow. Therefore, the larger the flow value is, the better the fluidity is. Fig. 4 shows the results of the slump test. The flow value of the flyash cement slurry and the antiwashout mortal mixture was smaller than that of the VTFC. Based on this result, as the pumpability of the VTFC exceeds that of the other samples, VTFC is able to be injected into the joints of sheet piles easier than other tested materials. That is to say, it is suggested that the narrow space at the joint of a steel pipe sheet pile can also be filled easily using VTFC.

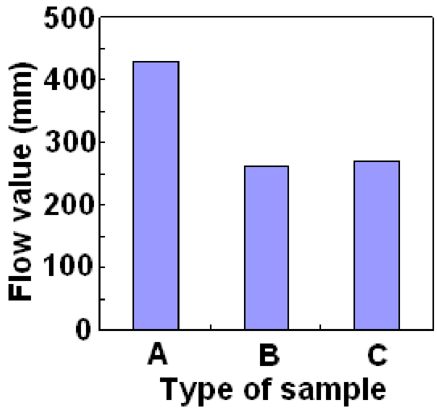
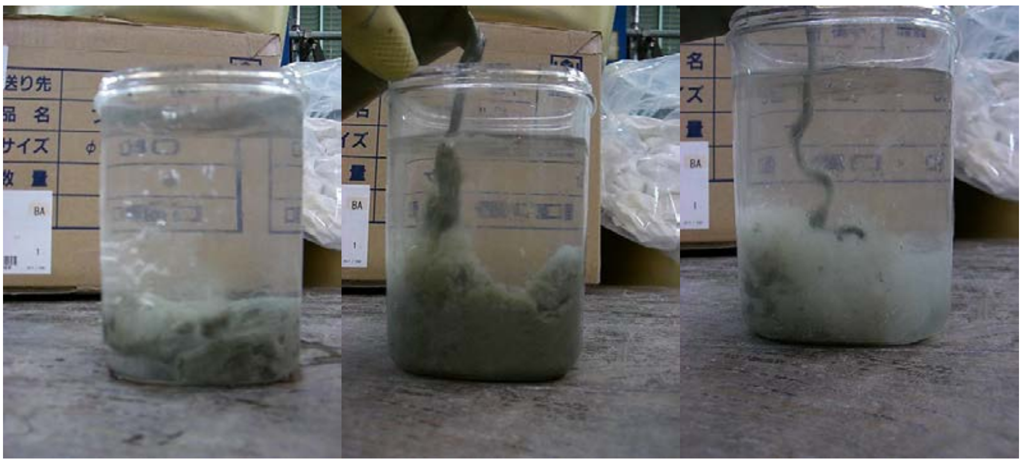
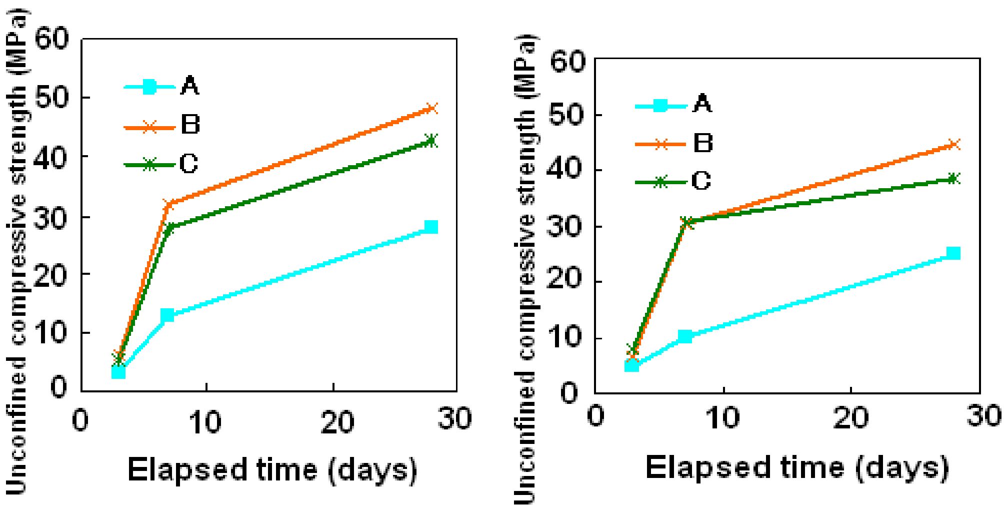


FIG. 4 RESULTS OF SLUMP TEST



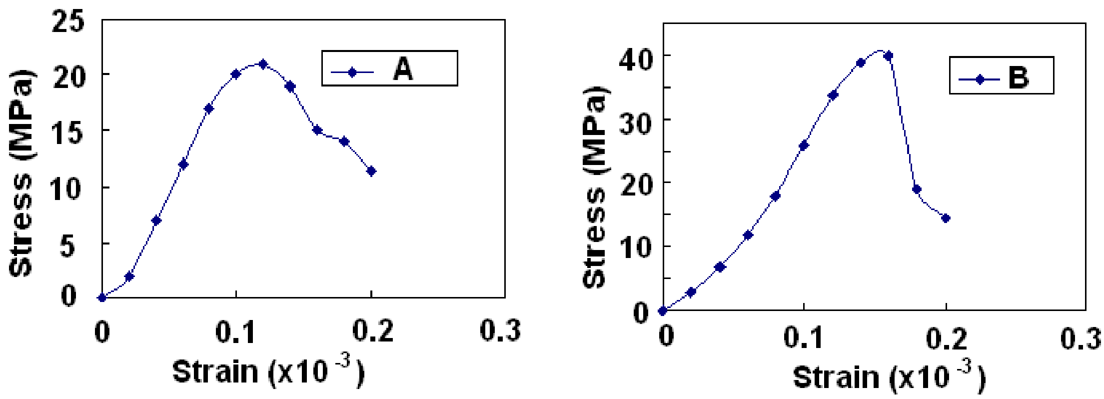
(A) VTFC (B) FC (C) AM

FIG. 3 AMOUNT COMBINATION OF EACH COMPONENT

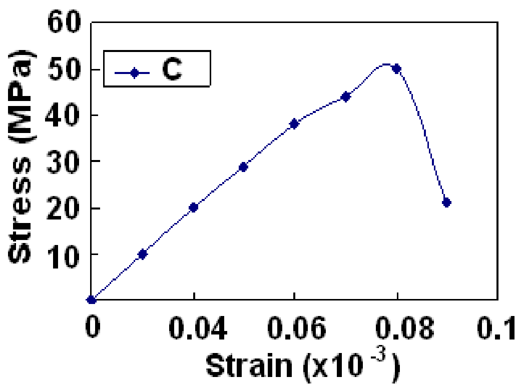


(A) PURE WATER CURING (B) SEA WATER CURING

FIG. 5 RELATIONSHIP BETWEEN THE CURING TIME AND MECHANICAL PROPERTIES



(A) VTFC (B) FC



(C) AM

FIG. 6 STRESS-STRAIN CURVE

Mechanical Strength Parameter; Unconfined Compressive Strength Test and Permeability Test

When flyash is added to Portland cement, the same kinds of oxides in the cement for making concrete are present (Shimada *et al.*, 2003). As an injection component, flyash acts, in part, as a fine aggregate and, in part, as a binding component. Fortunately, there is no substantial alteration in the properties of the original component (Davis, 1949, Joshi and Rosauer, 1973).

A cylindrical mold 50 mm in diameter and 100 mm depth was used to produce the specimens. The considered curing time for the specimens was 3, 7, 14 and 28 days, respectively, and an unconfined compressive strength test was performed on the

specimens after the aforementioned curing period. Each type of strength test was run on 5 to 10 specimens and the results were averaged to obtain the mean value of their properties.

Fig. 5 (a) and (b) show the relationship between the curing time and the mechanical properties of the samples for both pure water curing and sea water curing. As the figure shows, increasing the curing time inproves the mechanical properties. This is due to cement hydration reaction. The strength of VTFC is about half that of other samples. From these results, it is clarified that the addition of Viscotop as a surfactant does not work well to enhance the mechanical properties of the mixture more than that without Viscotop, however, VTFC is better for this application as up to 24MPa is generally required for the reinforcement of steel sheet pile joints (Hozumi *et al.*, 2006). In addition, it shows that the unconfined compressive strength of the sample which was tested using seawater curing is less than that of pure water curing. This is the reason for the deterioration of the internal texture of the cement due to generation of Ettringite, which is formed by the reaction of the sulphate and the calcium hydroxide in cement.

Fig. 6 (a)-(c) show the stress-strain curves of the unconfined compressive strength test for all samples. The result of VTFC shows an elastic behavior after failure. Conversely, the curves of FC and AM show rapid decline after the peak stress, like a ductile material. From this point, it is understood that the joint of a sheet pile filled with VTFC can bear the impact of tides and waves.

Table 2 lists the results of the permeability test. This result shows that the permeability of VTFC is the smallest. According to this result, it is indicated that VTFC is more water resistant than other samples. That is, it can be said that VTFC not only has beneficial water resistant qualities as a sealing material but is also more resistant to erosion, protecting the integrity of the cement.

TABLE 2 RESULTS OF PERMEABILITY TEST

	A	B	C
Permeability coefficient (cm/s)	2.9×10^{-7}	9.8×10^{-7}	9.4×10^{-7}

Relationship Between Strength and Local Position; Mortar Free Fall Injection Test

A tremie pipe of about 150-300mm in diameter is generally used for mortar injection in offshore structures, since the joints of sheet piles are quite narrow for injecting mortar. Thus, it is continuously injected from near the center section of the joint using a hose 25-32mm in diameter, which is smaller than a tremie pipe. However, according to the difference of specific gravity of each component of a sample, strength is not uniform at the local position after injection due to separation sedimentation from each component. Then, in order to consider the difference of strength at the local position after injection, a mortar free fall injection test was carried out as shown in Fig. 7.

An acrylic pipe with a diameter of 75 mm was modeled from the joint of a sheet pile and then divided into half, and one half of which was fastened to the other using clips, in order to simulate the diffusion of each component of a sample to water. After the pipe was set in the tank with water, a sample was injected into the acrylic pipe by the injection hose located 300 mm from the bottom of the pipe. The sample was taken out from the pipe at the 7th day of curing after injection. The sample was cut into three segments; the upper part, the bottom part and the center part. Each part was 150 mm in height, as shown in Fig. 7.

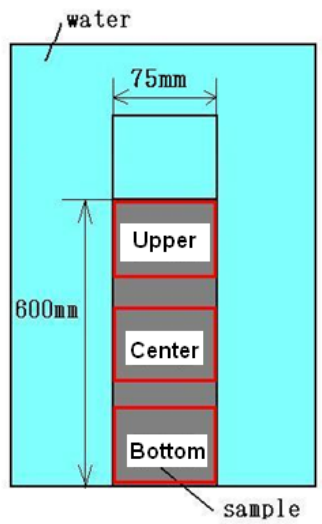


FIG. 7 DEVICE OF MORTAR FREE FALL INJECTION TEST

The results are shown in Fig. 8. First, the strength of the bottom part of the sample, C (AM), is the largest, and the strength decreases with the increasing height of the local position. This is the reason why flocculation occurred after the non-separated additive agent in an antiwashout mortar absorbed the sand and the cement. The strength of the bottom part of sample B (FC) is the lowest, remarkably, because the component of flyash and cement is dispersed into water and the aggregate components settled to the

bottom. Conversely, although the strength of the bottom part was inferior, the uniform strength of sample A (VTFC) was obtained due to the surfactant.

Therefore, it can be said that the flyash cement mixed with the surfactant Viscotop is a superior material for use in offshore structures, for example, as an injection material for the joints of sheet piles.

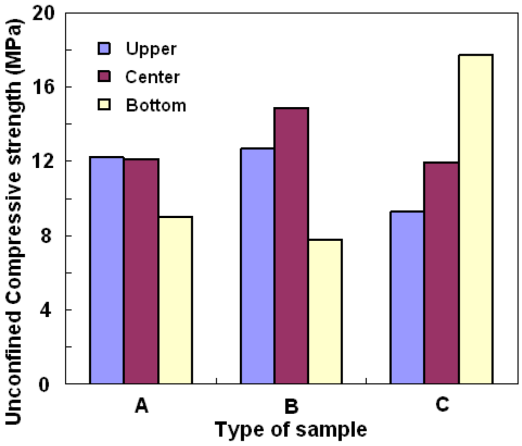


FIG. 8 RESULTS OF MORTAR FREE FALL INJECTION TEST

Conclusions

In this study, the utilization of flyash cement as well as flyash cement surfactant mixtures as injection materials for use in offshore structures was considered. The following conclusions can be deduced from this study:

1. It is clear that VTFC does not diffuse in water due to the effect of the surfactant.
2. It is easier for VTFC to be injected into the joints of sheet piles than that for antiwashout mortar and flyash cement.
3. It is understood that the joints of sheet piles filled using VTFC can bear the impact of tides or waves.
4. VTFC performs not only as a water resistant sealing material but also provides resistance to cement erosion.
5. VTFC has a uniform strength after injection.

From these conclusions, it is clear that VTFC can is sufficient for use as an alternative of antiwashout mortar.

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